INDOOR AIR QUALITY ASSESSMENT

Watertown Fire Department, Station 3
270 Orchard Street
Watertown, MA 02472

Prepared by:
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Center for Environmental Health
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Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the Watertown Fire Fighters Union, Local 1347, an indoor air quality assessment was conducted at the Watertown Fire Department (WFD), Station 3 at 270 Orchard Street, Watertown, Massachusetts. In response, the Watertown Health Department was notified, and an assessment was conducted by the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH) Bureau of Environmental Health Assessment (BEHA). On February 10, 2005, a visit to conduct an indoor air quality assessment was made to Station 3 by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program.

The station is a two-story red brick building was constructed in the early 1950s. The station reportedly underwent interior renovations from 2001 to 2002. The ground floor contains the engine bays and storage areas for fire fighting equipment. Two garage doors enclose each engine bay. The second floor contains a bunkhouse (for overnight staff), office space, kitchen and lounge. Windows are openable throughout the building. A stairwell connects the engine bays to the second floor. Fire poles with access to the engine bays are located in the second floor hallway near berthing/office areas.

Methods

Air tests for carbon dioxide, carbon monoxide (CO), temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of 20 (five per shift). The station is visited by approximately two to five members of the public on a daily basis. The tests were taken under normal operating conditions. Test results for general air quality parameters (e.g., carbon dioxide, temperature and relative humidity) appear in Table 1. A second round of tests for UFPs and CO were taken after operating emergency response vehicles after a simulated call. These results are listed in Table 2.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all occupied areas surveyed, indicating adequate air exchange. Mechanical ventilation is provided by a rooftop air-handling unit (AHU) equipped with high efficiency pleated air filters (Picture 1). However, WFD staff could not identify the date of the last filter change for the AHU. CEH staff examined the AHU and found the filter occluded with dirt and dust (Picture 1). The AHUs provide conditioned outside air through ducted ceiling vents (Picture 2), and air is returned to the AHUs via ducted wall or ceiling-mounted vents (Picture 3). Thermostats that control the HVAC system have fan settings of “on” and “automatic”. Thermostats set to the “automatic” setting were observed during the assessment (Picture 4). The automatic setting of the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings in occupied areas were measured in a range of 69° F to 70° F, which were slightly below and at the lower end of the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements in occupied areas ranged from 34 to 46 percent, which were below the BEHA recommended comfort guidelines in several areas. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A number of areas had water-damaged ceiling tiles (Picture 5). Occupants reported that ceiling tiles became damaged as a result of roof leaks that had since been repaired. Water-damaged ceiling tiles can provide a source of mold and should be replaced after a moisture source or leak is discovered and repaired.

Vehicle Exhaust

Under normal conditions, several sources of environmental pollutants can be present in a firehouse. These sources of pollutants, which primarily stem from fire vehicle operation, may include:

- Vehicle exhaust, which contains carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids, which contain volatile organic compounds (VOCs);
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Fire residues on vehicles, hoses and fire-turnout gear.

Of particular importance is vehicle exhaust. The use of fossil fuel-powered equipment (e.g., propane heaters, diesel or gasoline-powered vehicles, acetylene welding) involves the process of combustion. The process of combustion produces airborne liquids, solids and gases (NFPA, 1997). Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, carbon monoxide and particulate matter can produce health effects upon exposure. In order to assess whether contaminants generated by diesel engines were migrating into occupied areas of the station, measurements for carbon monoxide and airborne particulates were taken and used to pinpoint the source/pathway of combustion products.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce acute (immediate) health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency (US EPA) has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were measured in a range of 0-1 ppm. Carbon monoxide levels measured indoors the day of the assessment ranged from 0-4 ppm (Table 2). The measurement of 4 ppm was taken in the engine bay several minutes after fire apparatus returned.

Using carbon monoxide measurements alone to detect sources of combustion pollutants has limitations. If combustion pollutants are allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. As discussed, combustion of fossil fuels can also produce particulate matter of a small diameter [10 micrometers (μm)]. For this reason, a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas.

The US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter (μg/m3) in a 24-hour average.

BEHA staff conducted air monitoring for airborne particulate with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitoring is useful for tracking and identifying the source of airborne pollutants by counting the actual number of airborne particles. The source of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or whether particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether NAAQS PM10 standards have been exceeded. The primary purpose of these tests is identifying and reducing/preventing pollutant pathways.

Air monitoring for ultrafine particles (UFPs) was conducted around doors and hatches that provide access to the engine bay. Monitoring was also conducted in several areas on the first and second floor of the station. Measurements were taken prior to and after diesel engine operation. UFP readings ranged from 11.1 p/cc^3 to 35.2 p/cc^3 (Table 2). The highest reading for UFPs was taken in the engine bay, after diesel engine operation. These measurements would be expected during the normal operation of motor vehicles in an indoor environment.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling. The local exhaust system consists of a series of exhaust vents that feed into a main duct connected to a large exhaust motor located in the exterior wall of engine bay (Pictures 6 and 7). Make up air is provided through louvered vents on exterior walls of the engine bay (Pictures 7 and 8). The activation of the system appears to be dependent on the detection of carbon monoxide and nitrogen dioxide levels measured by sensors (Pictures 9 and 10). Once a pre-set reading is exceeded, the local exhaust system is activated to introduce fresh air and remove exhaust emissions. Therefore, no mechanical exhaust ventilation is provided until the set-point is exceeded to activate the system.

As discussed, BEHA staff had the WFD personnel simulate a call, in which all fire-fighting and emergency support vehicles were started, removed from and returned to the engine bay. Neither during this activity nor after did the local exhaust system activate to remove vehicle emissions. In addition, WFD personnel could not identify what the set-points for the chemical sensors were or the last time they were serviced and/or calibrated. However, approximately 5-10 minutes after the simulated call, CEH staff observed a member of the WFD activate the system via a manual override switch.

A number of pathways for vehicle exhaust and other pollutants to move from the engine bays into occupied areas on both the first and second floors were identified (Figure 1). The main pathways for vehicle exhaust emissions are the stairwell off the engine bay and around fire poles on the second floor. Although the stairwell is equipped with a door, it was observed propped open during the assessment (Picture 11). In addition, the door at the top of the stairwell had spaces beneath the door from which light could be seen penetrating (Pictures 12 and 13). These spaces can allow vehicle exhaust emissions and particulates to migrate into the stairwell and subsequently into living quarters and office space on the second floor.

Other potential pathways include spaces around fire poles and utility holes. Fire poles are not enclosed with a standard “clamshell”-type of opening, but instead are outfitted with fabricated metal doors or hatches that do not close completely. Spaces in and around these doors create a means for airborne pollutants to migrate into occupied areas (Pictures 14 and 15). The ceiling/walls of the engine bays are penetrated by holes for utilities. These holes can present potential pathways into occupied areas if they are not airtight. Each of these conditions presents a pathway for air to move from the engine bays to occupied areas of the station. In order to understand how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be considered:

- Heated air will create upward air movement, known as the stack effect.
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts influences the movement of odors from the first to the second floor and dispatch office. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bays can place the garage under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, these pollutant pathways should be sealed.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Manually activate local exhaust system upon exiting *and* returning to engine bays.
2. Contact the manufacture and/or installer regarding the operation and calibration of the chemical sensor/local exhaust ventilation system. Maintain and calibrate it in accordance with the manufacturer's instructions.
3. Ensure stairwell door leading off the engine bay, as well as the door at the top of the stairwell are closed. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts.
4. Consider installing an automatic control to activate the engine bay exhaust system as engine bay doors open.
5. Ensure all utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.

6. Work with town officials to develop a preventative maintenance program for all HVAC equipment department wide.
7. Operate thermostats in the fan “on” setting during occupancy to provide continuous air circulation.
8. Change filters for HVAC equipment as per the manufacturer’s instructions or more frequently if needed.
9. Balance mechanical ventilation systems every five years, as recommended by ventilation industrial standards (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
11. Ensure roof leaks are repaired. Replace water-damaged ceiling tiles. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.
12. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials

are available at the MDPH's website:

http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

NFPA. 1997. Fire Protection Handbook. 18th ed. Cote, A.E., ed. National Fire Protection Association, Quincy, MA.

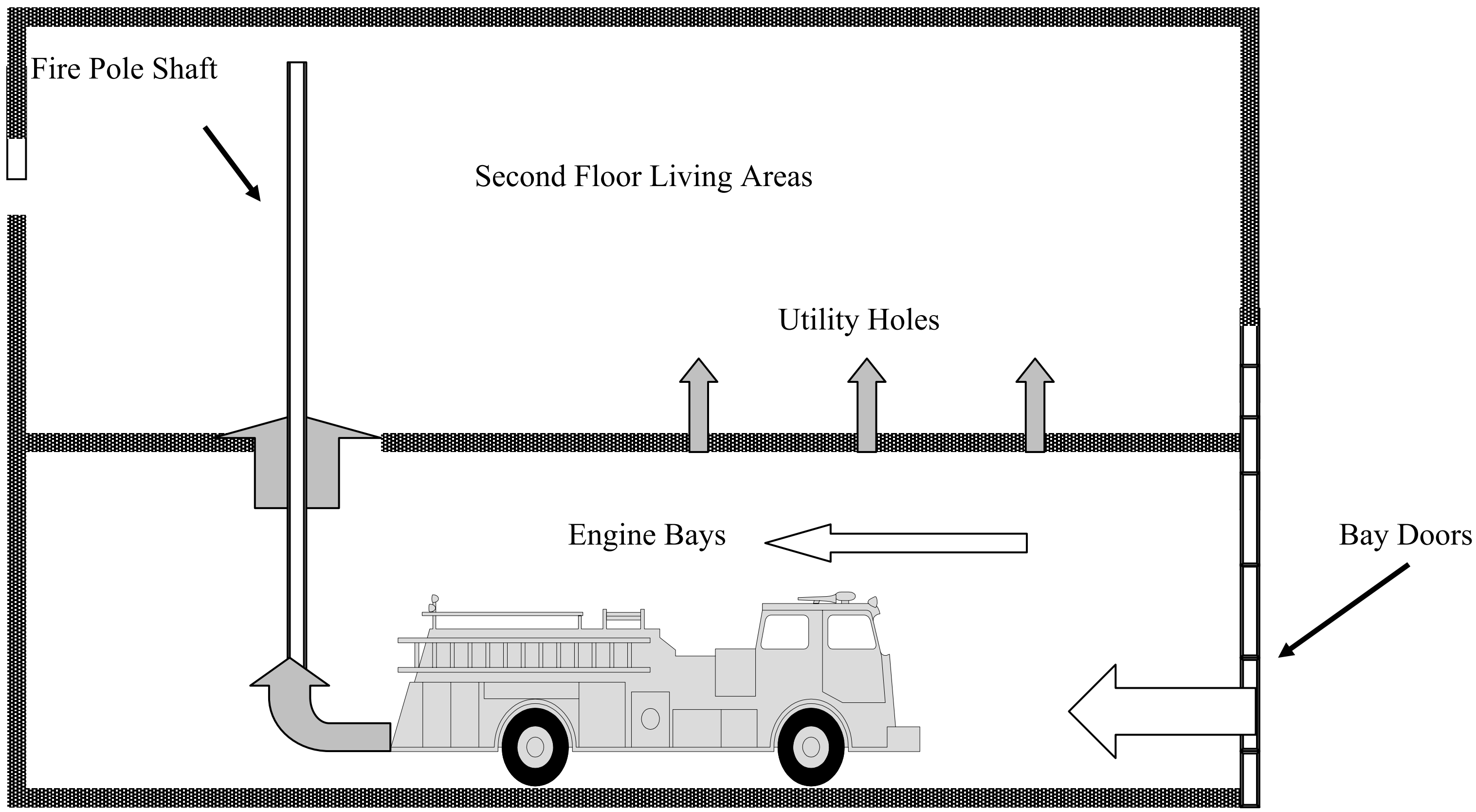
OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

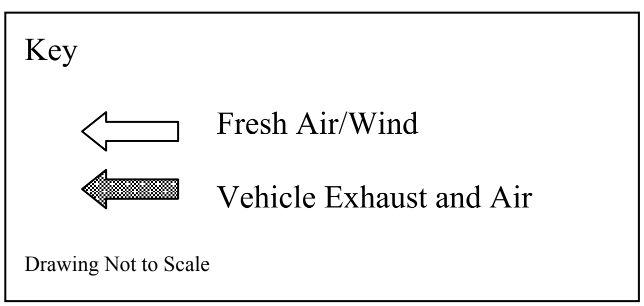
SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2000. National Ambient Air Standards (NAAQS). US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

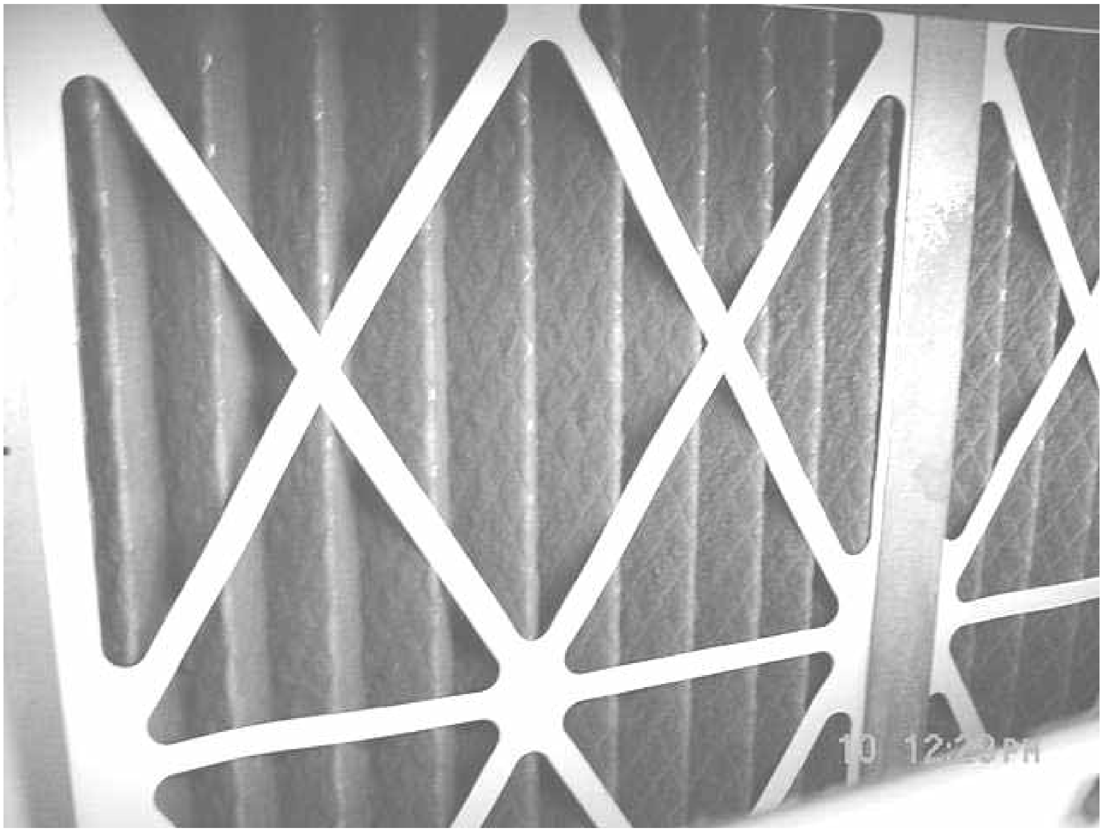
Figure 1 **Potential Pathways of Air and Pollutant Movement from Engine Bays into Occupied Areas***



* Note exhaust is minimized via the vehicle exhaust ventilation system



Picture 1



High-Efficiency Pleated Air Filter in Rooftop AHU

Picture 2

Ceiling-Mounted Air Diffuser

Picture 3

Wall-Mounted Return Vent

Picture 4

HVAC Thermostat Fan Set to "Auto" Setting

Picture 5

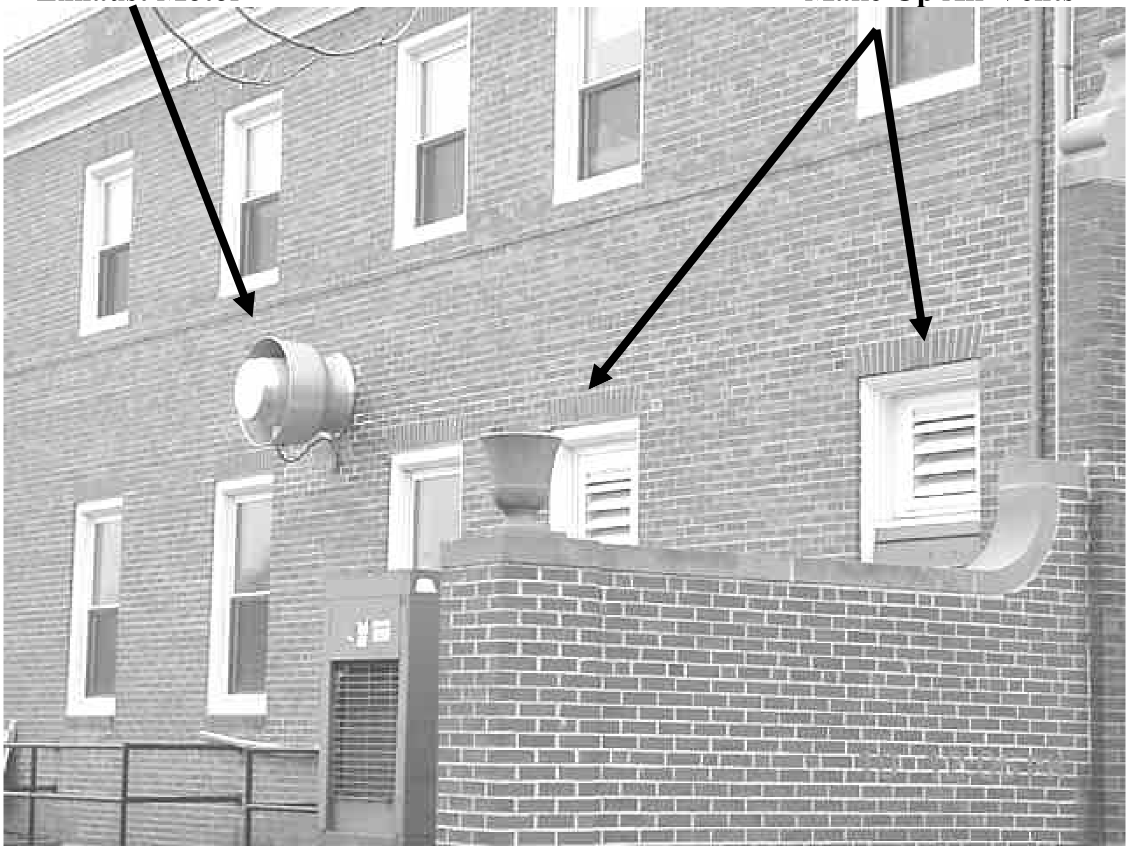
Missing/Water Damaged Ceiling Tiles

Picture 6

Ducted Local Exhaust Vents in Engine Bay

Picture 7

Exhaust Motor **Make-Up Air Vents**



Exterior Wall of Engine Bay Showing Exhaust Motor and Supply Vents for Local Exhaust System

Picture 8

Interior View of Louvered Make-Up Air Vent for Local Exhaust System

Picture 9

Chemical Sensor Alarm Panel for Local Exhaust System in Engine Bay

Picture 10

Digital Readout for Carbon Monoxide in Engine Bay

Picture 11

Stairwell Door to Engine Bay Propped Open

Picture 12

Door at top of Engine Bay Stairwell, Picture Taken From Inside Hallway

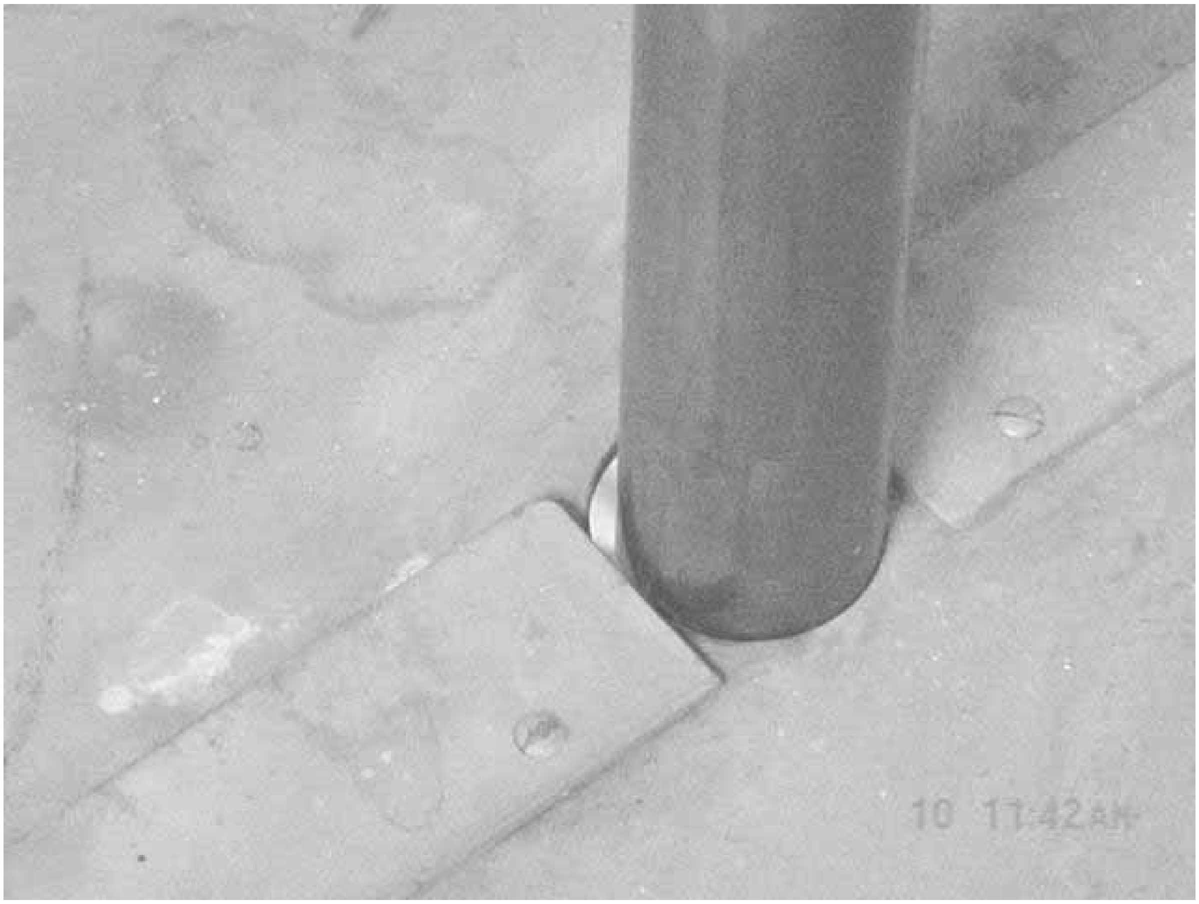
Picture 13

Light Penetrating Beneath Engine Bay Stairwell Door Shown in Picture 12, Picture Taken from inside Stairwell

Picture 14

Metal Doors over Fire Pole Opening

Picture 15



Spaces around Fire Pole

TABLE 1

Indoor Air Test Results – Fire Dept. Station 3, 270 Orchard St., Watertown, MA – February 10, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Background	380	39	93					Moderate to heavy rain, light wind, dense fog
Engine Bay	444	65	50	2	N	N	Y	Stairwell door propped open
Stairwell top landing	472	66	47	0	N	N	N	Spaces under door, door does not close tightly, lingering odors from vehicles
2nd Floor Hallway	533	70	42	0	N	Y	Y	
Lounge	524	69	46	2	Y	Y	Y	Fire pole-corner
Kitchen	616	69	46	4	Y	Y	Y	Water damaged ceiling tiles
Room 6	392	69	44	1	Y	Y	Y	2 windows open
Room 4	443	70	40	0	Y	Y	Y	
Room 2	521	69	44	0	Y	Y	Y	

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
Fire Dept. Station 3, 270 Orchard St., Watertown, MA – February 10, 2005

Location	Carbon Monoxide (**ppm) Before	Carbon Monoxide (**ppm) After	Ultrafine Particulates 1000p/cc^3 Before	Ultrafine Particulates 1000p/cc^3 After	Comments
Background	0-1	2	18.8	28.8	Moderate traffic
Engine Bay	1	4	35.2*	179.00	*Rescue vehicle returned approx 20 min prior to first reading-lingering emission/odors
Stairwell Top Landing	1	1	32.1*	53.0	Hallway door does not close completely, door at bottom of stairwell-left open by WFD staff
Lounge	0-1	0-1	20.0	24.4	
Kitchen	ND	ND	17.0	19.6	Gas oven/range
Firepole 1 (corner of lounge)	1	1	22.9	51.6	Spaces around firepole access hatch-
2nd Floor Hallway	ND	1	14.4	21.0	
Room 6	ND	ND	11.1	12.9	2 windows open
Room 4	ND	ND	12.9	13.0	
Room 2	ND	ND	14.0	17.4	

**** ppm = parts per million parts of air**

- **testing before and after starting diesel engines and response vehicles for simulated call**
- **ND = non-detectable**